

Future Hadron Physics Facilities at Fermilab

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Abstract. Fermilab's hadron physics research continues in all its accelerator-based programs. These efforts will be identified, and the optimization of the Fermilab schedules for physics will be described. In addition to the immediate plans, the Fermilab Long Range Plan will be cited, and the status and potential role of a new proton source, the Proton Driver, will be described.

1. Hadron Physics at Fermilab

Hadron physics is found in three areas of accelerator physics at Fermilab: the Tevatron collider experiments, the neutrino program, and fixed target physics with beams from the Main Injector. At the collider, CDF and DZero are in the midst of a multi-year run now, and BTeV is scheduled to take over as soon as these programs are ended. In the neutrino program, we have MiniBooNE using beam from the Booster accelerator now, and will be turning on NuMI, the neutrino program using beam from the Main Injector, in a few weeks. The MINOS experiment will operate with the neutrino beams as soon as they are available, and the MINERvA experiment has been approved to join as soon as it can be built. Finally, there is the MIPP experiment, E907 - Main Injector Particle Production, finishing its commissioning run now, and about to get its physics data. Also approved for the 120 GeV Main Injector program is a Drell-Yan experiment (E906), which is starting to build its detector this year. The possibility of returning to run for kaon physics using beam from the Main Injector is retained.

The Fermilab accelerator experiment schedules through 2009 are available on the web at

http://www.fnal.gov/directorate/program_planning/schedule/index.html

Optimization of running conditions is a challenge with such a diverse program, especially since each component of the Fermilab program has its own preference for how we should operate the accelerator complex, particularly the proton source.

The Tevatron Collider benefits from as rapid a cycling of the upstream accelerators as is consistent with antiproton beam-cooling times in the Accumulator and Recycler rings, with as much beam as acceptable for losses. The neutrino program can use even more rapid cycle times, with as much beam as acceptable for losses. For neutrinos, there is no lower limit on how fast the proton source accelerators should cycle. At the opposite extreme is the so-called SY120/Fixed Target program, which depends on experiment and test-beam user status. During set up, multiple, somewhat short duration spills per minute is optimal. During data taking, long cycles with long spills are best for maximizing integrated spill seconds by minimizing end

effects. The Office of Program Planning is charged with organizing all this by coordinating between experiments and the accelerator, under given guidelines from Director. At the moment, for example, there is the following guideline on the use of beam time for SY120:

The integrated effect of running SY120 beam will not reduce the antiproton stacking rate by more than 5% globally, with the details of scheduling to be worked out between the experimenters and the Office of Program Planning.

Note that this guideline is flexible, leaving the details of spill length and rate open to maximize the physics of the SY120 program. We also have the flexibility of mixing the various spill configurations in the accelerator time line sequence, adding an element of flexibility - and complexity.

2. Fermilab's Long Range Plan

The Fermilab Director established the Fermilab Long Range Planning Committee (LRPC) in the spring of 2003. An excerpt from the charge to the LRPC states:

I would like the Long-range Planning Committee to develop in detail a few realistically achievable options for the Fermilab program in the next decade under each possible outcome for the Linear Collider.

It was clear from the start that a new intense proton source to serve long baseline neutrino experiments and to provide other new physics options at Fermilab was one such option. A LRPC working group, with Bob Kephart as chairman, was charged to explore this option. The full LRPC received recommendations from this working group. The recommendations were subsequently adopted in the final FLRPC report and by the Director.

3. Fermilab Proton Source

3.1. Introduction

The Fermilab Linear Accelerator and Booster are old machines. At the same time, there is a desire for significantly more intense proton sources for long baseline neutrino physics. In order to meet the new demands, a new proton source will need to be constructed. The high level parameters desired for such a new facility at Fermilab are:

- 0.5 – 2.0 MW beam power at 8 GeV
- 2.0 MW beam power at 120 GeV, 6 times the power of the current Main Injector

There are two possible implementations being considered at Fermilab; an 8 GeV synchrotron and an 8 GeV superconducting rf linear accelerator. A web page has been established to track the progress on such a new proton source, the Proton Driver:

<http://www-bd.fnal.gov/pdriver/>

Currently, most of the accelerator effort is focused on bringing design for the linear accelerator to the same level as that for the synchrotron so that a final choice and proposal can be made. However, it is safe to say that there is particular appreciation for some linear accelerator advantages: better performance, flexibility, and the connection and possible synergies with an International Linear Collider (ILC), now that "cold" technology has been chosen for the latter.

3.2. Main Injector Upgrades

For either choice of 8 GeV injector (synchrotron or linear accelerator) the beam in the Main Injector will increase by a factor of 5 from its design value of $3.0 \cdot 10^{13}$ protons per pulse to $\sim 1.5 \cdot 10^{14}$ protons per cycle. The Main Injector beam power could also be increased by shortening the Main Injector ramp time. This would require additional magnet power supplies, and could be done prior to a Proton Driver as a first step. Both more protons per cycle and faster ramp times imply more rf power, meaning money is required.

3.3. Proton Driver Status and Plans

The recent International Technology Recommendation Panel opted for a "cold" technology for the International Linear Collider. This recommendation, and its wide acceptance, has provided a huge boost for a super-conducting rf linear-accelerator-based Proton Driver at Fermilab. Fermilab has been working on both warm and cold linear-collider-related technology. In FY 2005, all this effort will be dedicated to cold technology, also advancing a linear-accelerator Proton Driver. So, FY 2005 will see as much as a factor of two increase in super-conducting R&D spending at Fermilab relative to FY 2004. Plans are forming for a SCRF Module Test Facility (SMTF) to be built in the Meson East area at Fermilab. Long lead-time items like modulators are already being ordered.

3.4. Time Scale for a Proton Driver

It seems likely that a new, more intense proton source will be proposed for construction at Fermilab in the relatively near future. Such a project would be similar in scope to the Main Injector Project (i.e., for cost and schedule). An 8 GeV synchrotron and a superconducting rf linear accelerator both appear to be technically possible. The linear accelerator is strongly preferred by many, if it can be made affordable. The Fermilab management has requested that an 8 GeV linear accelerator design be developed, including cost and schedule information. Fermilab's Bill Foster is leading a team to develop the technical design.

It is always hard to guess about time scales. A technically limited schedule (when was the last time this happened?) could have the following DOE construction project critical decision (CD) schedule:

- CD-0 (statement of need) submitted in 2005
- CD-1 (preliminary acquisition strategy, project execution plan, conceptual design report, project scope, baseline cost/schedule range, project management plan, hazard analysis, etc.) submitted in 2006
- CD-2/3a (project baseline approved, approval to start construction) in 2007-8.

As usual, the availability of funding from DOE may push this schedule later. Once funding is approved, typical projects of this scale (the Fermilab Main Injector, SLAC B-factory, Spallation Neutron Source) have construction times of 4-5 years. The time scale will also depend on how the International Linear Collider plays out over the next few years (e.g., could the Proton Driver be seen as an ILC Engineering Test Facility?).

4. Proton Driver - The Physics Case

4.1. Introduction

It is up to users to make the physics case that a Proton Driver is required, and that it should be built as soon as possible. Making the physics case is crucial in all of this! A workshop to think about the broadest physics potential of a Proton Driver was just held. The program, with links to talks can be found at the above Proton Driver web page.

Steve Geer has been asked to organize the documentation of the physics case. A strong physics case, coupled to a machine technical design, will make it possible to submit a Proton Driver project to the DOE for approval and funding. The recent Proton Driver Workshop was a step in this process. Information on the workshop and talks can be found linked to the web page:

<http://www-td.fnal.gov/projects/PD/PhysicsIncludes/Workshop/index.html>

Three of the working groups at the workshop may be most interesting for hadron physics:

- WG2 on Neutrino Interactions – Jorge Morfin (Fermilab), Rex Tayloe (Indiana), Ron Ransome (Rutgers), conveners
- WG4 on Kaons/Pions – Hogan Nguyen (Fermilab) and Taku Yamanaka (Osaka), conveners
- WG5 on Antiprotons – Dave Christian (Fermilab) and Mark Mandelkern (UC-Irvine), conveners

While not represented at the workshop, there is also a working group on neutrons. The workshop, of course, had additional working groups less connected to hadron physics.

In each case, the working groups identified physics measurements of interest to the particle and nuclear physics communities in the era of a Proton Driver. However, in principle, some of the measurements discussed at the workshop could be made sooner. Organizing to make these earlier measurements may focus a part of the research community in anticipation of a Proton Driver. It would be easier then to do the experiments which depend on the flux available from a Proton Driver.

4.2. Neutrino Working Group

The Neutrino Working Group included the following physics topics in its discussion of goals:

- Strange quark contribution and axial form factor through parity violation
- Duality
- Coherent pion production
- Exclusive resonant final states
- Parton distribution functions, particularly at high x_{Bj}
 - Generalized parton distribution functions including quark flavor dependence through the weak analog of deeply-virtual Compton scattering $n(\nu, \gamma)p$
 - Detailed study of nuclear effects with neutrinos that are expected to be significantly different than those measured with charged leptons
- Spin-dependent distribution measurements using polarized targets
- A-dependence and more detailed nuclear effects

4.3. Kaon and Pion Working Group

In the case of the Kaon and Pion Working Group, the following were among the topics discussed:

- Production dynamics for exotic/rare quark and gluon states
- Rare pion decays, e.g., improving V_{ud} from pion beta decay in flight
- CKM parameters via $K \rightarrow \pi \nu \bar{\nu}$
- Pushing further in $K \rightarrow \pi l l$ in the search for new physics

Many of these measurements can be expected to help define the nature of the high mass objects which are anticipated to be found at the Tevatron or the LHC.

4.4. Proton Driver Study - Next Steps

The Proton Driver Working Group draft reports will go to a Proton Driver Science Advisory Committee (PDSAC)[1], whose chair is Peter Meyers (Princeton). The PDSAC is composed of particle and nuclear physicists, and is international in composition. The plan is to have the PDSAC review conveners' presentations and the reports in order to advise the Laboratory on the strongest physics motivations for a Proton Driver. A draft statement of the physics case (a statement of need) could be ready for reading over the winter holidays. Then, a final draft statement of the physics case could be prepared for submission to DOE.

5. Final Comments

I have focused on a only part of the hadron physics in Fermilab's future. This part is dominantly proposal driven. I have not said much about the collider or MIPP, which are covered in separate talks at this First Meeting of the APS Topical Group on Hadron Physics. In its vision of the future at Fermilab, the Long Range Plan says

Fermilab will remain the primary site for accelerator-based particle physics in the U.S. in the next decade and beyond.

Defining the future of much of hadron physics at Fermilab, e.g., use of neutrinos, hadron beams, and even Tevatron beams will depend on the users. What will be the total available beam? Will we build a Proton Driver? What fraction of the available protons will go to hadron physics? Will a stretcher ring be proposed and built?

A robust program depends on robust interest, and eventually, compelling physics-driven experiment proposals. We may hope this meeting of the Topical Group on Hadron Physics, and related gatherings in the future, will contribute directly to that robust program.

Acknowledgments

Much of the material on the Proton Driver is taken from the presentation by Bob Kephart on October 6, 2004, to the Proton Driver workshop at Fermilab. Thanks also go to David Christian, Hugh Montgomery, Hogan Nguyen, and Jorge Morfin for comments on a draft of this paper.

References

[1] The membership of the Proton Driver Science Advisory Committee is:

- Peter Meyers, Princeton University, USA, chair
- Ed Blucher, University of Chicago, USA
- Gerhard Buchalla, Ludwig-Maximilians University, Munich, Germany
- John Dainton, University of Liverpool, UK
- Yves Declais, LAPP-IN2P3-CNRS Annecy, France
- Lance Dixon, SLAC, USA
- Umberto Dosselli, INFN and University of Padua, Italy
- Don Geesaman, Argonne National Laboratory, USA
- Geoff Greene, Oak Ridge National Laboratory, USA
- Taka Kondo, KEK, Japan
- Marvin Marshak, University of Minnesota, USA
- Bill Molzon, University of California-Irvine, USA
- Hitoshi Murayama, University of California-Berkeley, USA
- Jim Siegrist, University of California-Berkeley, USA
- Tony Thomas, Thomas Jefferson National Laboratory, USA
- Taku Yamanaka, Osaka University, Japan